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# Effect of running on different terrains in combination with sports-specific conditioning on selected motor fitness and respiratory parameters among soccer players

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**Abstract**
The purpose of the present study was to examine the effect of running on different terrains combined with sports-specific conditioning on selected motor fitness and respiratory parameters among intercollegiate soccer players. Sixty male soccer players aged 18–22 years were randomly assigned into four groups: firm surface running with sports-specific conditioning, sand surface running with sports-specific conditioning, artificial grass running with sports-specific conditioning, and a control group. The experimental training was conducted for eight weeks, three days per week. Leg strength (squat 1 RM), speed (50-m dash), maximal oxygen uptake ($VO_2$ max), and vital capacity were assessed before and after the training period. Paired t-test, analysis of covariance (ANCOVA), and Scheffé's post-hoc test were used for statistical analysis at the 0.05 level of significance. The results revealed significant improvements in all selected variables for the experimental groups, while the control group showed no significant changes. Among the experimental groups, the sand surface training group demonstrated significantly greater improvements in leg strength, speed, $VO_2$ max, and vital capacity compared to the firm surface and artificial grass groups. The findings indicate that running on sand combined with sports-specific conditioning elicits superior neuromuscular and respiratory adaptations due to increased mechanical and physiological demands. It is concluded that sand-based training is a more effective conditioning strategy for enhancing motor fitness and respiratory efficiency in soccer players.

**Keywords:** $VO_2$ max, sand surface training, sports-specific conditioning, leg strength, speed, vital capacity, soccer players

## Introduction
Soccer is a high-intensity, intermittent team sport that demands exceptional motor fitness and respiratory efficiency from players (Gaudino *et al*., 2014) [6]. Throughout a match, athletes must execute repeated actions such as sprinting, accelerating, decelerating, jumping, tackling, and sustained running. Success in moderateern soccer hinges on the ability to generate forceful lower-limb actions repeatedly while maintaining high work rates with minimal fatigue. Thus, key motor fitness components like leg strength and speed are vital, as they underpin explosive movements, kicking power, and movement economy (Silva *et al*., 2015) [14]. Similarly, respiratory parameters such as maximal oxygen uptake ($VO_2$ max) and vital capacity are essential for sustaining performance, enabling efficient oxygen utilization and rapid recovery during intermittent efforts (Binnie *et al*., 2014) [4].
Running-based conditioning remains a cornerstone of soccer training programs. However, recent advancements in training science highlight that the training surface significantly influences adaptations (Pereira *et al*., 2021) [10]. Different terrains firm ground, sand, and artificial grass impose unique mechanical, neuromuscular, and metabolic demands (Sanchez-Sanchez *et al*., 2020) [13]. Firm surfaces facilitate efficient force application, commonly used in traditional conditioning. Sand, with its instability and reduced stiffness, increases muscular workload and energy expenditure, potentially leading to greater neuromuscular gains (Pinnington & Dawson, 2001; Binnie *et al*., 2013) [11, 5]. Artificial grass offers moderateerate resistance with lower impact stress, bridging the two extremes (Loturco *et al*., 2023) [9].
Leg strength is crucial for generating ground reaction forces during sprints, jumps, and changes of direction, while speed enables positional advantages and quick transitions (Arazi *et al*., 2024) [3].

Training on compliant surfaces like sand may enhance muscle activation in the lower extremities, promoting strength improvements (Impellizzeri *et al.*, 2008) [7]. Respiratory efficiency, reflected in $VO_2$ max (a marker of aerobic capacity) and vital capacity (maximum lung volume), supports endurance in soccer's burst-and-recovery profile (Yigit & Tuncel, 1998) [15]. Higher $VO_2$ max allows sustained high-intensity efforts, and improved vital capacity enhances oxygen availability (Andrade *et al.*, 2021) [1].

Sports-specific conditioning, which mimics match-like movement patterns and energy demands, can amplify these adaptations when paired with terrain-based running (Silva *et al.*, 2015) [14]. Despite the growing use of such methods, evidence on their combined effects on leg strength, speed, $VO_2$ max, and vital capacity in competitive soccer players is limited. This study examines the impact of running on firm surfaces, sand, and artificial grass, combined with sports-specific conditioning, compared to a control group maintaining regular training. We hypothesized that sand-based training would elicit superior improvements in all variables due to its heightened physiological and mechanical demands, followed by artificial grass and firm surfaces (Pereira *et al.*, 2023) [9].

## Methodology

### Selection of Subjects

Sixty male intercollegiate soccer players, aged between 18 and 22 years, were selected from different colleges. All the participants had represented their respective institutions at the intercollegiate level, ensuring adequate exposure to the physical and physiological demands of competitive soccer. The inclusion criteria required the players to be medically fit, free from musculoskeletal injuries, and actively engaged in regular soccer training. Players with any history of cardiorespiratory disorders or recent injuries were excluded from the study. Prior to the commencement of the experimental programme, the purpose and procedures of the study were clearly explained to the subjects, informed consent was obtained, and ethical approval was secured from the institutional ethics committee.

### Study Design

The present study employed a randomized controlled pre-test and post-test design to examine the effect of running on different terrains in combination with sports-specific conditioning on selected motor fitness and respiratory parameters. Random allocation of subjects minimized initial group differences and ensured internal validity. The experimental period lasted for eight weeks, which is considered sufficient to elicit meaningful adaptations in motor fitness and respiratory variables among trained athletes.

### Training Protocol

Training sessions were conducted on designated running surfaces corresponding to each experimental group in order to standardize training conditions. The subjects were randomly assigned into three experimental groups and one control group with fifteen players in each group. Group I underwent running on a firm surface combined with sports-specific conditioning, Group II underwent running on sand surface combined with sports-specific conditioning, Group III underwent running on artificial grass combined with sports-specific conditioning, and Group IV (control) maintained their regular soccer training without additional terrain-based running or sports-specific conditioning. All experimental groups trained three non-consecutive days per week for a duration of eight weeks. Each training session lasted approximately 60 minutes and included a 15-minute warm-up, the main running and conditioning activities, and a 5-10 minutes cool-down period. The warm-up consisted of dynamic stretching and low-intensity running at 40–50% of maximum heart rate. Training intensity was progressively increased by manipulating repetitions, sets, and running intensity. All sessions were supervised by qualified coaches to ensure safety and adherence to the training protocol.

### Data Collection

Leg strength was assessed using the squat 1 RM test, which is a commonly accepted measure of lower-limb strength. Speed was measured using the 50-meter dash test, and the best performance was recorded for analysis. $VO_2$ max was estimated using the Cooper 12-minute run and walk test, which provides a valid field-based assessment of aerobic capacity. Vital capacity was measured using a spirometer following standard testing procedures. All measurements were taken one week before and immediately after the completion of the eight-week training programme.

### Training Schedule

Sports-specific conditioning drills such as sprinting with ball, directional changes, shuttle runs, and agility-based movements were incorporated in all training sessions for the experimental groups to simulate match situations and enhance training transfer.

**Week 1-4**

| Component | Exercise | Sets | Reps | Duration | Intensity | Rest/Reps | Rest/Sets |
|---|---|---|---|---|---|---|---|
| **Day 1** | | | | | | | |
| Running | Continuous Running | 1 | | 30 min | 60–65% | | |
| | Strides run | 3 | | 20m × 5 | Moderate | | 1 min |
| Conditioning | Dribbling Cone Weave | 2 | 3 | 3 min | Moderate | 45 sec | 1 min |
| | Inside–Out Dribble | 2 | 3 | 3 min | Moderate | 45 sec | 1 min |
| | Short Passes | 2 | 20 | — | Low–Moderate | 30 sec | 1 min |
| | First Touch Receiving Drill | 2 | 1 | 3 min | Low–Moderate | 45 sec | 1 min |
| | Wall Passing Drill | 2 | 1 | 3 min | Low–Moderate | 45 sec | 1 min |
| **Day 2** | | | | | | | |
| Running | 20 m Shuttle Run | 4 | 1 | 20 m × 6 | Moderate | 1 min | 1.5 min |
| | Zig-Zag Running | 4 | 1 | 15–20 m | Moderate | Walk-back | 1 min |
| | Acceleration–Deceleration Run | 3 | 1 | 10–20–10 m | Moderate | 45 sec | 90 sec |
| Conditioning | Gate Passing Drill | 2 | 1 | 5 min | Moderate | — | 1 min |
| | Rondo 3v1 | 2 | 1 | 4 min | Low–Moderate | — | 1 min |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Triangle Passing | 2 | 1 | 5 min | Moderateerate | — | 1 min |
| | Calf Raises | 3 | 12 | — | Low | 30 sec | 1 min |
| **Day 3** | | | | | | | |
| Running | Fast Continuous Running | 1 | 1 | 15 min | 70% | — | — |
| | Flying Sprints | 3 | 1 | 20 m build-up + 20 m max speed | Moderate–High | Walk-back | 1 min |
| | T-Run (Agility) | 3 | 1 | — | Moderate | 45 sec | 1 min |
| Conditioning | 1v1 Feint Dribble | 2 | 2 | 4 min | Moderate | 1 min | 1 min |
| | 10 m Finishing | 2 | 5 | — | Moderate | 45 sec | 1 min |
| | Shooting Accuracy | 2 | 6 | — | Moderate | 45 sec | 1 min |
| | Dribble–Turn–Shoot | 2 | 1 | 4 min | Moderate | 45 sec | 1 min |

**Week 5–8**

| Component | Exercise | Sets | Reps | Duration | Intensity | Rest/Reps | Rest/Sets |
|---|---|---|---|---|---|---|---|
| **Day 1** | | | | | | | |
| Running | Interval Running | 5 | 1 | 5 min | 70–80% | — | 90 sec |
| | 50 m Sprint | 5 | 1 | — | High | Walk-back | 1 min |
| | High-Knee Intervals | 3 | 25 m | — | High | 30 sec | 1 min |
| Conditioning | Speed Dribble + Shoot | 3 | 2 | 7 min | High | 60 sec | 1 min |
| | Partners Pass Relay | 3 | 2 | 6 min | Moderate | 60 sec | 1 min |
| | Moving Shots | 3 | 5 | — | Moderate–High | 45 sec | 1 min |
| | First Touch Receiving | 2 | 1 | 4 min | Moderate | 45 sec | 1 min |
| | Rondo 4v1 | 2 | 1 | 5 min | Moderate | — | 1 min |
| **Day 2** | | | | | | | |
| Running | Zig-Zag Running | 5 | 1 | 20 m | High | Walk-back | 1 min |
| | Shuttle Run | 4 | 1 | 20 m × 8 | 75–80% | 1 min | 1.5 min |
| | Pyramid Run | 3 | 1 | 30–40–50–40–30 m | Moderate–High | Walk-back | 1.5 min |
| Conditioning | Inside–Out Dribble | 3 | 3 | 4 min | Moderate | 45 sec | 1 min |
| | Quick Pass + Receive | 3 | 1 | 6 min | Moderate | 45 sec | 1 min |
| | Broad Jumps | 3 | 8 | — | High | 45 sec | 1 min |
| | Wall Passing (one-touch) | 2 | 1 | 4 min | Moderate | 45 sec | 1 min |
| | Combination Play 1–2 Pass | 2 | 1 | 5 min | High | — | 1 min |
| **Day 3** | | | | | | | |
| Running | Tempo Run | 1 | 1 | 15 min | 75% | — | — |
| | 30 m Speed Runs | 6 | 1 | 30 m | High | Walk-back | 1 min |
| | Acceleration–Deceleration | 3 | 1 | 10–20–10 m | High | 45 sec | 1 min |
| Conditioning | 1v1 Feint | 3 | 2 | 5 min | High | 1 min | 1 min |
| | Two-Touch Passing | 2 | 1 | 7 min | Moderate | — | 1 min |
| | Shooting Accuracy | 3 | 8 | — | High | 45 sec | 1 min |
| | Dribble-Turn-Shoot | 2 | 1 | 5 min | High | 45 sec | 1 min |

**Statistical Analysis**

The collected data were statistically analysed using SPSS software. Descriptive statistics were used to determine means and standard deviations. Paired t-test was applied to assess within-group differences between pre-test and post-test scores. Analysis of covariance (ANCOVA) was employed to determine differences among the adjusted post-test means of the experimental groups, using pre-test scores as covariates. Scheffé's post hoc test was used to identify specific group differences. The level of significance was set at 0.05.

**Results:** The present study examined the effect of running on different terrains in combination with sports-specific conditioning on selected motor fitness and respiratory parameters, namely leg strength, speed, $VO_2$ max, and vital capacity among soccer players. Paired t-tests were employed to determine within-group differences between pre-test and post-test scores. Analysis of covariance (ANCOVA) was used to assess between-group differences by adjusting for pre-test variations, and Scheffé's post hoc test was applied to identify specific group differences.

**Table 1:** Paired t-test results and percentage gain for leg strength (Squat 1 RM)

| Group | Pre-Test Mean (SD) | Post-Test Mean (SD) | Mean Difference | T-Value | % Gain |
|---|---|---|---|---|---|
| Firm Surface | 91.2 (8.2) | 99.4 (9.0) | 8.2 | 10.21 | 9.00 |
| Sand Surface | 90.8 (8.0) | 106.5 (8.3) | 15.7 | 17.12 | 17.29 |
| Artificial Grass | 91.0 (9.2) | 100.4 (9.5) | 9.4 | 10.55 | 10.33 |
| Control | 90.9 (5.2) | 92.2 (9.1) | 1.3 | 0.91 | 1.43 |

*Significant at 0.05 level for the DF of 14 is 2.15

The above table revealed significant improvements in leg strength for all the experimental groups following the training intervention. The obtained paired t-values of 10.21 for the Firm Surface group, 17.12 for the Sand Surface group, and 10.55 for the Artificial Grass group exceeded the critical value at the 0.05 level of significance with the respective degrees of freedom, indicating meaningful effects of the training programmes. The control group showed no significant improvement (t=0.91). The magnitude of improvement was further substantiated by the percentage gains, which showed a 17.29% increase in leg strength for the Sand Surface group, a 10.33% increase for the Artificial Grass group, a 9.00% increase for the Firm Surface group, and a 1.43% increase for the control group. These findings clearly demonstrate that, although the three experimental training programmes were effective in enhancing leg strength, training on sand produced the greatest improvement, while firm surface and artificial grass training resulted in moderate but significant gains. The control group showed minimal improvement.

**Table 2:** ANCOVA for Leg Strength (Squat 1 RM)

| Test | Firm Surface | Sand Surface | Artificial Grass | Control | Source of Variance | Sum of Squares | DF | Mean Square | F-ratio |
|---|---|---|---|---|---|---|---|---|---|
| Pre-Test Mean | 91.2 | 90.8 | 91.0 | 90.9 | Between | 1.21 | 3 | 0.40 | 0.01 |
| | | | | | Within | 3389.45 | 56 | 60.53 | |
| Post-Test Mean | 99.4 | 106.5 | 100.4 | 92.2 | Between | 1542.88 | 3 | 514.29 | 6.43* |
| | | | | | Within | 4473.12 | 56 | 79.88 | |
| Adjusted Post-Test Mean | 99.3 | 106.6 | 100.3 | 92.3 | Between | 1542.88 | 3 | 514.29 | 31.18* |
| | | | | | Within | 908.74 | 55 | 16.52 | |

*Significant at 0.05 level. Table value for DF 3 to 56 & 3 to 55 is approx. 2.78

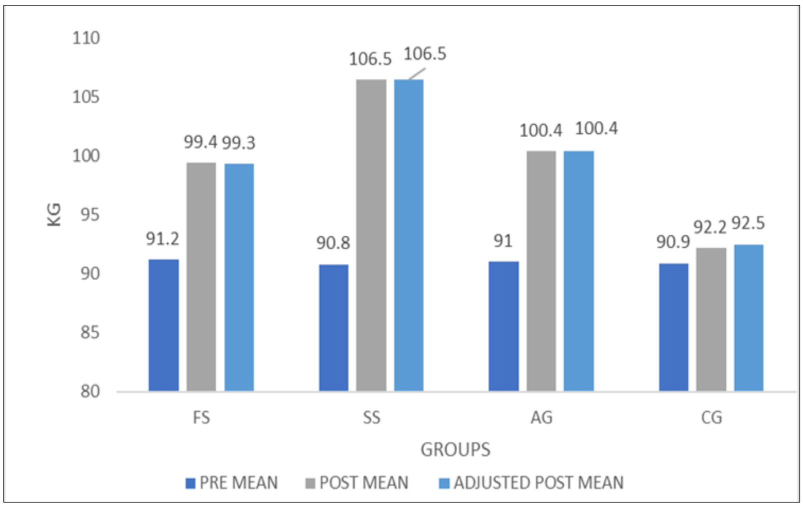
The ANCOVA results for leg strength (squat 1 RM) revealed no significant difference among the four groups at the pre-test level, as the obtained F-ratio of 0.01 was lower than the required table value of 2.78 at the 0.05 level of significance. This indicates that the Firm Surface, Sand Surface, Artificial Grass, and Control groups were comparable in leg strength before the commencement of the training programme. At the post-test level, a significant difference was observed among the groups, as the obtained F-ratio of 6.43 exceeded the critical value at the 0.05 level. This clearly indicates that the training interventions had a significant effect on leg strength. Further, after adjusting the post-test means for pre-test differences using ANCOVA, the adjusted post-test F-ratio was found to be 31.18, which was also much higher than the required table value, confirming a statistically significant difference among the groups even after controlling for initial variations. The adjusted post-test means scores showed that the Sand Surface group (106.6) achieved the highest improvement in leg strength, followed by the Artificial Grass group (100.3) and the Firm Surface group (99.3), while the Control group (92.3) recorded the lowest adjusted mean. These findings suggest that although the experimental training surfaces contributed to improvements in leg strength, sand surface training was significantly more effective than the others, and all experimental groups outperformed the control.

**Table 3:** Scheffé's Post-Hoc Test-Leg Strength (Squat 1 RM).

| FS | SS | AG | Control | M.D | C.I |
|---|---|---|---|---|---|
| 99.3 | 106.6 | | | 7.3* | 4.29 |
| 99.3 | | 100.3 | | 1.0 | |
| 99.3 | | | 92.3 | 7.0* | |
| | 106.6 | 100.3 | | 6.3* | |
| | 106.6 | | 92.3 | 14.3* | |
| | | 100.3 | 92.3 | 8.0* | |

*Significant at 0.05 level.

The above table reveals that the mean differences in leg strength between the Firm Surface and Sand Surface groups (7.3), Firm Surface and Control groups (7.0), Sand Surface and Artificial Grass groups (6.3), Sand Surface and Control groups (14.3), and Artificial Grass and Control groups (8.0) were greater than the required confidence interval value of 4.29 at the 0.05 level of significance. These results confirm that sand surface training produced significantly greater improvements in leg strength when compared with the other groups, and the experimental groups generally outperformed the control. However, the mean difference between the Firm Surface and Artificial Grass groups (1.0) was lower than the required confidence interval value, indicating no significant difference in this case. Overall, the findings indicate that although the experimental training programmes contributed to improvements in leg strength, training on sand elicited significantly superior gains compared to the other conditions, with the control showing the least improvement.




**Graph 1:** Pre post and adjusted means of Leg strength

**Table 4:** Paired t-test results and percentage gain for speed

| Group | Pre-Test Mean (SD) | Post-Test Mean (SD) | Mean Difference | T-Value | % Gain |
|---|---|---|---|---|---|
| Firm Surface | 7.11 (0.3) | 6.71 (0.3) | 0.60 | 8.09 | 5.89 |
| Sand Surface | 7.22 (0.2) | 6.60(0.3) | 0.62 | 10.05 | 7.42 |
| Artificial Grass | 7.1 (0.2) | 6.71 (0.4) | 0.36 | 5.53 | 5.04 |
| Control | 7.19 (0.3) | 7.1 (0.4) | 0.09 | 1.69 | 1.25 |

*Significant at 0.05 level for the DF of 14 is 2.15

The above table revealed significant improvements in speed for all the experimental groups, as indicated by the reduction in mean scores from pre-test to post-test. The obtained paired t-values of 8.09 for the Firm Surface group, 10.05 for the Sand Surface group, and -5.53 for the Artificial Grass group were greater than the required critical value at the 0.05 level of significance, demonstrating that the observed changes were statistically significant and attributable to the training intervention. The control group showed no significant improvement (T=1.69). The magnitude of improvement was further supported by the percentage gains. The Sand Surface group showed the highest improvement with a 7.42% gain, reflecting a greater reduction in performance time and indicating superior adaptation to the training stimulus. The Firm Surface group recorded a percentage gain of 5.89%, the Artificial Grass group 5.04%, and the control group 1.25%. These results suggest that although the experimental training programmes were effective in enhancing speed, training on sand was comparatively more effective than training on firm surface and artificial grass, with the control showing minimal gains.

**Table 5:** ANCOVA for Speed

| Test | Firm Surface | Sand Surface | Artificial Grass | Control | Source of Variance | Sum of Squares | DF | Mean Square | F-ratio |
|---|---|---|---|---|---|---|---|---|---|
| Pre-Test Mean | 7.11 | 7.22 | 7.10 | 7.19 | Between | 0.12 | 3 | 0.04 | 0.67 |
| | | | | | Within | 3.25 | 56 | 0.06 | |
| Post-Test Mean | 6.71 | 6.60 | 6.71 | 7.10 | Between | 1.71 | 3 | 0.57 | 4.69* |
| | | | | | Within | 6.82 | 56 | 0.12 | |
| Adjusted Post-Test Mean | 6.71 | 6.59 | 6.78 | 7.04 | Between | 1.71 | 3 | 0.57 | 12.34* |
| | | | | | Within | 2.54 | 55 | 0.05 | |

*Significant at 0.05 level. Table value for DF 3 to 56 & 3 to 55 is approx. 2.78

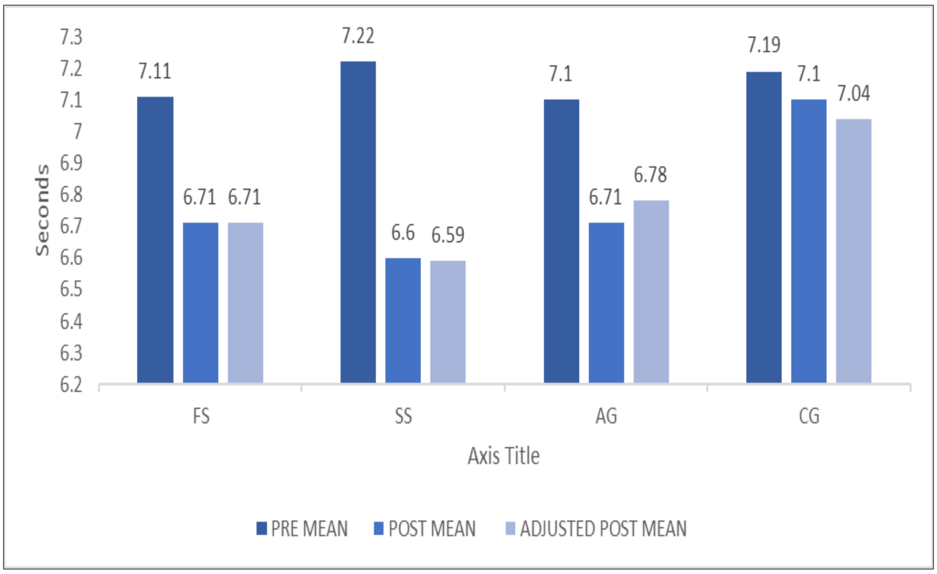
The ANCOVA results for speed indicated no significant difference among the four groups at the pre-test stage, as the obtained F-ratio of 0.67 was lower than the required table value of 2.78 at the 0.05 level of significance. This confirms that the Firm Surface, Sand Surface, Artificial Grass, and Control groups were statistically homogeneous in speed prior to the training intervention. At the post-test level, a significant difference was observed among the groups, with an obtained F-ratio of 4.69, which exceeded the critical value at the 0.05 level. This demonstrates that the training programmes produced a significant effect on speed performance. Further, after adjusting the post-test means for pre-test differences through ANCOVA, the adjusted post-test F-ratio increased to 12.34, which was also greater than the required table value, indicating a highly significant difference among the groups even after controlling for initial variations. The adjusted post-test means scores revealed that the Sand Surface group (6.59) achieved the greatest improvement in speed, as reflected by the lowest time value, followed by the Firm Surface group (6.71) and Artificial Grass group (6.78), while the Control group (7.04) showed comparatively lesser improvement. These findings suggest that although the experimental training programmes were effective in improving speed, training on sand was more effective, and all experimental groups outperformed the control.

**Table 6:** Scheffé's Post-Hoc Test-Speed

| FS | SS | AG | Control | M.D | C.I |
|---|---|---|---|---|---|
| 6.71 | 6.59 | | | 0.12 | 0.23 |
| 6.71 | | 6.78 | | 0.07 | |
| 6.71 | | | 7.04 | 0.33* | |
| | 6.59 | 6.78 | | 0.19 | |
| | 6.59 | | 7.04 | 0.45* | |
| | | 6.78 | 7.04 | 0.26* | |

*Significant at 0.05 level.

The above table reveals that the mean differences in speed between the Firm Surface and Control groups (0.33), Sand Surface and Control groups (0.45), and Artificial Grass and Control groups (0.26) were greater than the required confidence interval value of 0.23 at the 0.05 level of significance. These results confirm that the experimental groups produced significantly greater improvements in speed when compared with the control group. However, the mean differences between the Firm Surface and Sand Surface groups (0.12), Firm Surface and Artificial Grass groups (0.07), and Sand Surface and Artificial Grass groups (0.19) were lower than the required confidence interval value, indicating that there was no significant difference among the experimental groups. Overall, the findings indicate that although the experimental training programmes contributed to improvements in speed, they were superior to the control, with sand showing the best gains.




**Graph 2:** Pre post and adjusted means of speed

**Table 7:** Paired t-test results and percentage gain for $VO_2$ Max

| Group | Pre-Test Mean (SD) | Post-Test Mean (SD) | Mean Difference | T-Value | Percentage Gain (%) |
|---|---|---|---|---|---|
| Firm Surface | 47.0 (3.7) | 49.9 (4.4) | 3.0 | 4.79 | 6.30 |
| Sand Surface | 47.2 (3.4) | 53.3 (3.7) | 6.1 | 15.10 | 12.93 |
| Artificial Grass | 47.7 (2.4) | 51.8 (3.6) | 4.1 | 9.10 | 8.53 |
| Control | 45.9 (1.8) | 46.4 (2.4) | 0.5 | 1.24 | 1.12 |

*Significant at 0.05 level for the DF of 14 is 2.15

The above table revealed significant improvements in $VO_2$ max for all the experimental groups following the training intervention. The obtained paired t-values of 4.79 for the Firm Surface group, 15.10 for the Sand Surface group, and 9.10 for the Artificial Grass group exceeded the critical t-value at the 0.05 level of significance, indicating that the training programmes produced meaningful improvements in aerobic capacity. The control group showed no significant improvement (T=1.24). The extent of improvement was further reflected in the percentage gains. The Sand Surface group demonstrated the greatest enhancement in $VO_2$ max with a percentage gain of 12.93%, indicating superior cardiovascular adaptation due to the higher physiological demands of training on sand. The Artificial Grass group showed a moderate improvement with a percentage gain of 8.53%, the Firm Surface group 6.30%, and the control group 1.12%. These findings suggest that although the experimental training programmes were effective in improving $VO_2$ max, sand surface training was comparatively more effective, with the control showing minimal adaptation.

**Table 8:** ANCOVA for $VO_2$ Max

| Test | Firm Surface | Sand Surface | Artificial Grass | Control | Source of Variance | Sum of Squares | DF | Mean Square | F-Ratio |
|---|---|---|---|---|---|---|---|---|---|
| Pre-Test Mean | 47.0 | 47.2 | 47.7 | 46 | Between | 26.91 | 3 | 8.97 | 1.06 |
| | | | | | Within | 473.11 | 56 | 8.45 | |
| Post-Test Mean | 49.9 | 53.3 | 51.8 | 46.4 | Between | 398.13 | 3 | 132.71 | 10.21* |
| | | | | | Within | 728.15 | 56 | 13.00 | |
| Adjusted Post-Test Mean | 49.9 | 53.0 | 51.0 | 47.5 | Between | 398.13 | 3 | 132.71 | 38.31* |
| | | | | | Within | 190.52 | 55 | 3.46 | |

*Significant at 0.05 level. Table value for DF 3 to 56 & 3 to 55 is approx. 2.78

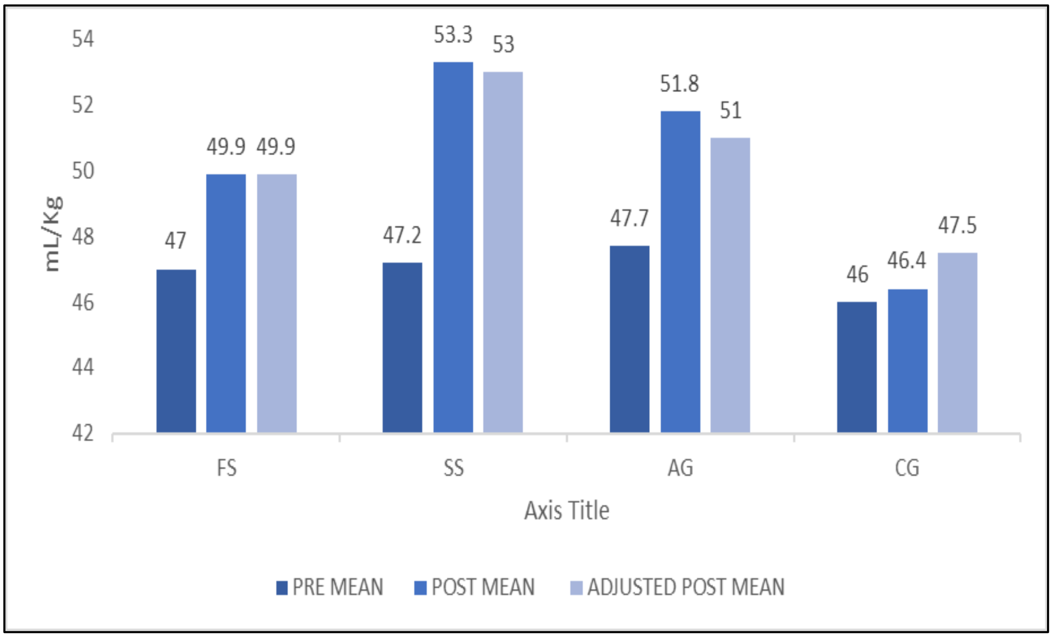
The ANCOVA results for $VO_2$ max showed no significant difference among the four groups at the pre-test level, as the obtained F-ratio of 1.06 was lower than the required table value at the 0.05 level of significance. This indicates that the Firm Surface, Sand Surface, Artificial Grass, and Control groups were comparable in aerobic capacity before the commencement of the training programme. At the post-test stage, a significant difference was observed among the groups, with an obtained F-ratio of 10.21, which exceeded the critical value at the 0.05 level, indicating that the training interventions had a significant effect on $VO_2$ max. Further, after adjusting the post-test means for pre-test differences using ANCOVA, the adjusted post-test F-ratio increased to 38.31, which was also higher than the required table value, confirming a statistically significant difference among the groups even after controlling for initial variations. The adjusted post-test means scores revealed that the Sand Surface group (53.0) attained the highest improvement in $VO_2$ max, followed by the Artificial Grass group (51.0) and Firm Surface group (49.9), while the Control group (47.5) showed comparatively lower improvement. These findings suggest that although the experimental training programmes were effective in enhancing aerobic capacity, sand surface training was significantly more effective, and all experimental groups outperformed the control.

**Table 9:** Scheffé's Post-Hoc Test-$VO_2$ Max

| FS | SS | AG | Control | M.D | C.I |
|---|---|---|---|---|---|
| 49.9 | 53.0 | | | 3.1* | 1.96 |
| 49.9 | | 51.0 | | 1.1 | |
| 49.9 | | | 47.5 | 2.4* | |
| | 53.0 | 51.0 | | 2.0* | |
| | 53.0 | | 47.5 | 5.5* | |
| | | 51.0 | 47.5 | 3.5* | |

*Significant at 0.05 level.

The above table reveals that the mean differences in $VO_2$ max between the Firm Surface and Sand Surface groups (3.1), Firm Surface and Control groups (2.4), Sand Surface and Artificial Grass groups (2.0), Sand Surface and Control groups (5.5), and Artificial Grass and Control groups (3.5) were greater than the required confidence interval value of 1.96 at the 0.05 level of significance. These results confirm that sand surface training produced significantly greater improvements in $VO_2$ max when compared with the other groups, and the experimental groups outperformed the control. However, the mean difference between the Firm Surface and Artificial Grass groups (1.1) was lower than the required confidence interval value, indicating that there was no significant difference between these two groups. Overall, the findings indicate that although the experimental training programmes were effective in improving $VO_2$ max, training on sand elicited significantly superior gains compared to the other conditions, with the control showing the least improvement.




**Graph 3:** Pre post and adjusted means of $Vo_2$ max

**Table 10:** Paired t-test results and percentage gain for vital capacity

| Group | Pre-Test Mean (SD) | Post-Test Mean (SD) | Mean Difference | T-Value | % Gain |
|---|---|---|---|---|---|
| Firm Surface | 4.1 (0.3) | 4.4 (0.5) | 0.3 | 4.83 | 6.92 |
| Sand Surface | 3.9 (0.4) | 4.4 (0.5) | 0.5 | 11.48 | 14.07 |
| Artificial Grass | 4.0 (0.5) | 4.2 (0.6) | 0.2 | 3.67 | 4.70 |
| Control | 3.8 (0.3) | 4.0 (0.4) | 0.1 | 2.08 | 3.66 |

*Significant at 0.05 level for the DF of 14 is 2.15

The above table revealed significant improvements in vital capacity for all the experimental groups following the training intervention. The obtained paired t-values of 4.83 for the Firm Surface group, 11.48 for the Sand Surface group, and 3.67 for the Artificial Grass group were greater than the required critical value at the 0.05 level of significance, indicating that the improvements from pre-test to post-test were statistically significant. The control group showed no significant improvement ($t=2.08$, $p=0.057$). The magnitude of improvement was further evidenced by the percentage gains. The Sand Surface group showed the highest improvement in vital capacity with a percentage gain of 14.07%, suggesting that training on sand elicited greater respiratory and physiological adaptations. The Firm Surface group demonstrated a moderateerate improvement with a percentage gain of 6.92%, the Artificial Grass group 4.70%, and the control group 3.66%. Overall, the findings indicate that although the experimental training programmes were effective in enhancing vital capacity, sand surface training was comparatively more effective, with the control showing lesser gains.

**Table 11:** ANCOVA for vital capacity

| Test | Firm Surface | Sand Surface | Artificial Grass | Control | Source of Variance | Sum of Squares | DF | Mean Square | F-Ratio |
|---|---|---|---|---|---|---|---|---|---|
| Pre-Test Mean | 4.1 | 3.9 | 4.0 | 3.8 | Between | 0.71 | 3 | 0.24 | 1.41 |
| | | | | | Within | 9.34 | 56 | 0.17 | |
| Post-Test Mean | 4.4 | 4.4 | 4.2 | 4.0 | Between | 1.76 | 3 | 0.59 | 2.53* |
| | | | | | Within | 13.03 | 56 | 0.23 | |
| Adjusted Post-Test Mean | 4.24 | 4.52 | 4.15 | 4.11 | Between | 1.76 | 3 | 0.59 | 11.98* |
| | | | | | Within | 2.70 | 55 | 0.05 | |

*Significant at 0.05 level, table value for DF 3 to 56 & 3 to 55 is approx. 2.78

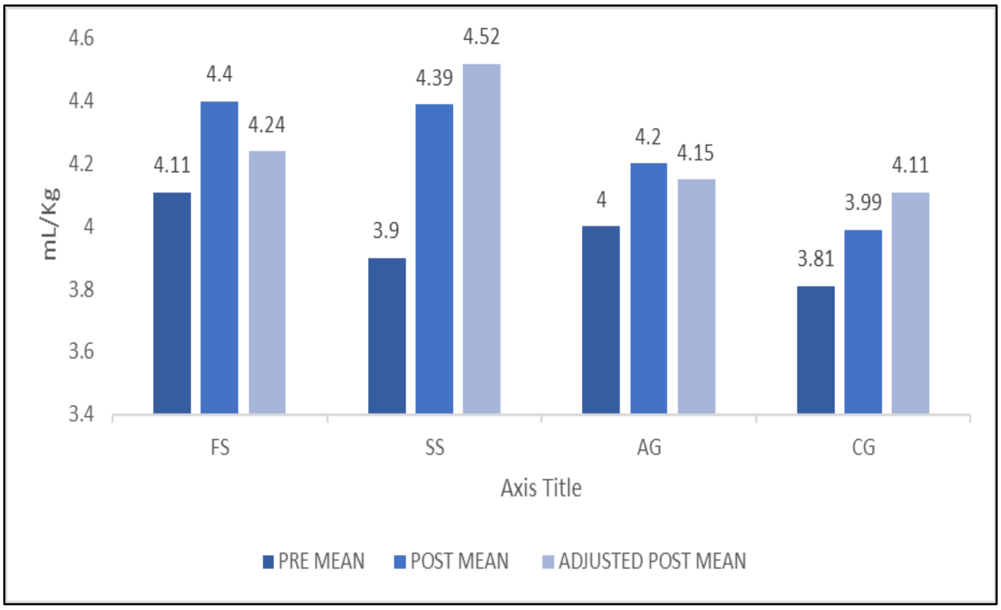
The ANCOVA results for vital capacity indicated no significant difference among the four groups at the pre-test stage, as the obtained F-ratio of 1.41 was lower than the required table value at the 0.05 level of significance. This confirms that the Firm Surface, Sand Surface, Artificial Grass, and Control groups were homogeneous with respect to vital capacity before the training intervention. At the post-test level, a significant difference was observed among the groups, with an obtained F-ratio of 2.53, which exceeded the critical value at the 0.05 level, indicating that the training programmes had a significant effect on vital capacity. Further, after adjusting the post-test means for pre-test differences through ANCOVA, the adjusted post-test F-ratio was found to be 11.98, which was also higher than the required table value, confirming a statistically significant difference among the groups even after controlling for initial variations. The adjusted post-test means scores revealed that the Sand Surface group (4.52) attained the highest improvement in vital capacity, followed by the Firm Surface group (4.24) and Artificial Grass group (4.15), while the Control group (4.11) showed comparatively lower improvement. These findings suggest that although the experimental training programmes were effective in improving vital capacity, sand surface training was significantly more effective, and the experimental groups generally outperformed the control.

**Table 12:** Scheffé's post-hoc test-vital capacity

| FS | SS | AG | Control | M.D | C.I |
|---|---|---|---|---|---|
| 4.24 | 4.52 | | | 0.28* | 0.23 |
| 4.24 | | 4.15 | | 0.09 | |
| 4.24 | | | 4.11 | 0.13 | |
| | 4.52 | 4.15 | | 0.37* | |
| | 4.52 | | 4.11 | 0.41* | |
| | | 4.15 | 4.11 | 0.04 | |

*Significant at 0.05 level.

The above table reveals that the mean differences in vital capacity between the Firm Surface and Sand Surface groups (0.28), Sand Surface and Artificial Grass groups (0.37), and Sand Surface and Control groups (0.41) were greater than the required confidence interval value of 0.23 at the 0.05 level of significance. These results confirm that sand surface training produced significantly greater improvements in vital capacity when compared with the other groups. However, the mean differences between the Firm Surface and Artificial Grass groups (0.09), Firm Surface and Control groups (0.13), and Artificial Grass and Control groups (0.04) were lower than the required confidence interval value, indicating that there was no significant difference between these groups. Overall, the findings indicate that although the experimental training programmes were effective in improving vital capacity, training on sand elicited significantly superior gains compared to the other conditions, with the control showing the least improvement.




**Graph 4:** Graph-Pre post and adjusted means of vital capacity

## Discussion

The findings of this study provide compelling evidence that terrain-specific running, when integrated with sports-specific conditioning, significantly enhances motor fitness and respiratory parameters in intercollegiate soccer players, with sand-based training emerging as the most effective modality. This aligns with the hypothesis that sand's unstable and compliant nature imposes greater mechanical and physiological demands, leading to superior adaptations compared to firm surfaces, artificial grass, and standard training (Pereira *et al*., 2023) [9]. The randomized controlled design, coupled with robust statistical analyses (e.g., ANCOVA F-ratios ranging from 11.98 to 38.31 across variables, all $p<0.05$), underscores the reliability of these outcomes, while percentage gains offer practical insights into the magnitude of improvements.

For leg strength, assessed via squat 1RM, the sand surface group exhibited the largest gain (17.29%), surpassing the artificial grass (10.33%) and firm surface (9.00%) groups, with the control showing negligible change (1.43%). Scheffé's post-hoc tests confirmed significant differences (mean differences > 4.29, $p<0.05$) between sand and other groups, except between firm and artificial grass. This superiority can be attributed to sand's reduced surface stiffness, which demands heightened neuromuscular activation and eccentric loading in lower-limb muscles, such as the quadriceps and hamstrings, to stabilize and propel the body (Impellizzeri *et al*., 2008) [7]. The increased muscle recruitment likely adheres to the overload principle, fostering greater force production and hypertrophy, as evidenced by similar findings in plyometric training on sand versus grass (Arazi *et al*., 2024) [3]. In soccer contexts, these enhancements translate to improved explosive actions like jumping and tackling, critical for match performance (Silva *et al*., 2015) [14].

Speed improvements, measured by the 50-m dash, followed a similar pattern, with the sand group achieving a 7.42% gain compared to 5.89% on firm surfaces, 5.04% on artificial grass, and 1.25% in the control. Although post-hoc analyses showed no significant inter-experimental differences (mean differences < 0.23, $p>0.05$), all experimental groups outperformed the control ($p<0.05$). Sand's compliant properties may refine stride mechanics by increasing ground contact time and requiring more forceful propulsion, thereby enhancing neuromuscular coordination and power output (Loturco *et al*., 2023) [9]. This is consistent with Pereira *et al*. (2021), who reported greater sprint velocity gains on sand due to elevated energy costs and muscle overload, which could optimize soccer-specific transitions and positional play (Gaudino *et al*., 2014) [6]. The lack of differentiation among terrains suggests that while sand excels, the integration of sports-specific drills (e.g., agility runs) may equalize speed adaptations across surfaces to some extent.

Respiratory parameters also demonstrated marked terrain-dependent effects. $VO_2$ max increased most substantially in the sand group (12.93%), followed by artificial grass (8.53%) and firm surfaces (6.30%), against 1.12% in the control. Post-hoc tests revealed significant differences (mean differences > 1.96, $p<0.05$) favoring sand over others, except between firm and artificial grass. Vital capacity mirrored this, with sand yielding 14.07% gains versus 6.92% on firm, 4.70% on artificial grass, and 3.66% in the control, with sand significantly outperforming all (mean differences > 0.23, $p<0.05$). These adaptations likely stem from sand's higher metabolic demands, which elevate oxygen consumption and respiratory effort to overcome instability, improving aerobic efficiency and lung expansion (Binnie *et al*., 2014; Andrade *et al*., 2021) [4, 1]. Supporting studies, such as Yigit and Tuncel (1998) [15], found sand endurance training doubled $VO_2$ max improvements over road running due to amplified internal loads, while Binnie *et al*. (2013) [5] linked sand's energy expenditure (Pinnington & Dawson, 2001) [11] to enhanced peak oxygen uptake in team-sport athletes. In soccer's intermittent profile, these gains facilitate better recovery between high-intensity bouts, reducing fatigue (Asadi *et al*., 2024) [3].

The integration of sports-specific conditioning likely amplified these effects by simulating match demands, such as directional changes and ball drills, which engage multiple energy systems and enhance transfer to gameplay (Ramirez-Campillo *et al*., 2020). However, the study's limitations warrant consideration. The sample was restricted to 60 male intercollegiate players aged 18-22 from a single region, limiting generalizability to females, professionals, or diverse populations (Sanchez-Sanchez *et al*., 2020) [13]. The 8-week duration captures acute adaptations but not long-term retention or potential plateaus. Field-based assessments (e.g., Cooper test for $VO_2$ max) offer practicality but may lack laboratory precision, introducing measurement variability. Without direct biomechanical data (e.g., electromyography) or controls for external factors (e.g., nutrition), inferred mechanisms remain speculative. Additionally, while no injuries were reported, sand's higher impact could pose risks over extended periods (Impellizzeri *et al*., 2008) [7].

Future research should extend to longer interventions, include female athletes to explore sex differences, and incorporate advanced metrics like wearable-derived heart rate variability or muscle activation patterns. Comparative studies on additional terrains (e.g., inclines) or hybrid protocols could refine applications, while investigating injury profiles would inform safety. Practically, these results advocate for coaches to incorporate sand training in periodized programs to maximize neuromuscular and respiratory gains, potentially elevating soccer performance at competitive levels.

## Conclusion

The present investigation demonstrates that incorporating running on different terrains in conjunction with sports-specific conditioning significantly enhances selected motor fitness components and respiratory parameters among intercollegiate soccer players. Notably, training on sand surfaces yielded the most substantial improvements across all measured variables leg strength (17.29%), speed (7.42%), $VO_2$ max (12.93%), and vital capacity (14.07%) compared to firm surfaces, artificial grass, and the control group. These superior gains can be attributed to the unique biomechanical and physiological demands imposed by sand, including increased energy expenditure, heightened neuromuscular activation, and greater metabolic stress, which collectively foster enhanced strength, explosive power, aerobic capacity, and pulmonary function. Firm surfaces and artificial grass also produced meaningful adaptations, albeit to a lesser extent, underscoring the value of terrain variation in optimizing training outcomes beyond conventional methods. The control group's minimal improvements further highlight the efficacy of the experimental protocols in eliciting targeted physiological responses tailored to soccer's high-intensity, intermittent nature.

## References


1. Andrade DC, Manzo O, Beltrán AR, Álvarez C, Rio DR, Toledo C, *et al*. High-intensity intermittent exercise performed on the sand induces higher internal load demands in soccer players. Front Psychol. 2021;12:713106.
2. Arazi H, Mohammadi M, Asadi A. Effect of 5-week plyometric training on sand versus grass on jumping and sprinting performance in under-20s soccer players. Int J Strength Cond. 2024;4(1):1-8.
3. Asadi A, Campillo RR, Arazi H, Villarreal SDE. Effects of sprint interval training surface on physical fitness attributes of collegiate female soccer players. J Sports Sci Med. 2024;23(2):465-472.
4. Binnie MJ, Dawson B, Arnot MA, Pinnington H, Landers G, Peeling P. Effect of sand versus grass training surfaces during an 8-week pre-season conditioning programme in team sport athletes. J Sports Sci. 2014;32(10):1001-1012.
5. Binnie MJ, Dawson B, Pinnington HC, Landers G, Peeling P. Effect of training surface on acute physiological responses after interval training in young men. J Strength Cond Res. 2013;27(4):1047-1056.
6. Gaudino P, Alberti G, Iaia FM. Estimated metabolic and mechanical demands during different small-sided games in elite soccer players. Hum Mov Sci. 2014;36:123-133.
7. Impellizzeri FM, Rampinini E, Castagna C, Martino F, Fiorini S, Riccetto M, *et al*. Effect of plyometric training on sand versus grass on muscle soreness and jumping and sprinting ability in soccer players. Br J Sports Med. 2008;42(1):42-46.
8. Loturco I, Pereira LA, Reis VP, Abad CCC, Freitas TT, Azevedo PHSM. Sprint and jump training on sand versus grass surfaces: Effects on the physical performance of young soccer players. J Strength Cond Res. 2023;37(9):1828-33.
9. Pereira LA, Freitas TT, Pivetti B, Alcaraz PE, Jeffreys I, Loturco I. Sand and grass surfaces are equally effective in promoting positive adaptations in the sprint performance of elite young soccer players. Biol Sport. 2023;40(1):177-183.
10. Pereira LA, Freitas TT, Campillo RR, Bishop C, Loturco I. Effects of training on sand or hard surfaces on sprint and jump performance of team-sport players: A systematic review with meta-analysis. Strength Cond J. 2021;43(3):56-66.
11. Pinnington HC, Dawson B. The energy cost of running on grass compared to soft dry beach sand. J Sci Med Sport. 2001;4(4):416-430.
12. Campillo RR, Andrade DC, Nikolaidis PT, Moran J, Clemente FM, Chaabene H, *et al*. Effects of plyometric jump training on vertical jump height of volleyball players: A systematic review with meta-analysis of randomized-controlled trials. J Sports Sci Med. 2020;19(3):489-499.
13. Sanchez SJ, Cervantes MJ, Serradilla DE, Romeo A, Los Arcos A. Effect of natural turf, artificial turf, and sand surfaces on sprint performance: A systematic review and meta-analysis. Int. J Environ Res Public Health. 2020;17(24):9478.
14. Silva JR, Nassis GP, Rebelo A. Strength training in soccer with a specific focus on highly trained players. Sports Med Open. 2015;1(1):17.
15. Yigit SS, Tuncel F. A comparison of the endurance training responses to road and sand running in high school and college students. J Strength Cond Res. 1998;12(2):79-81.